THE EFFECTS OF A STRETCHER-CARRY HARNESS ON SOLDIER PERFORMANCE: CARRYING FROM A REMOTE AREA

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This study investigated whether the use of a shoulder harness and team size would affect stretcher-carry performance and post-carry rifle marksmanship and fine-motor coordination following a carry from a remote site. Soldiers (12 male and 11 female) carried stretchers in two- and four-person teams, with and without a shoulder harness. Soldiers carried a stretcher at 4.8 km/hr for as long as possible, up to 30 min. Soldiers fired at targets and completed a fine-motor coordination task before and after each carry. Analysis of Variance and post-hoc Newman-Keuls Comparison of Means revealed significant rifle shooting impairments after stretcher-carrying ($p < 0.001$). Men carried the stretcher longer than women ($p < 0.0001$). Harness use and carrying in four-person teams prolonged carry time for both men and women, without decreasing shooting accuracy. Completion of a fine-motor coordination task was faster after using a harness vs a hand carry ($p = 0.03$) and working in four vs two-person teams ($p < 0.02$). Heart rate was lower during harness carries ($p < 0.001$). In conclusion, the ability to transport, medically treat, and protect patients is improved by harness use and working in four-person teams. It is suggested the policy of using four-person teams be enforced, and harness systems be included with the supply of stretchers for any situation that requires continuous stretcher-carrying of five minutes for four-person teams or two minutes for two-person teams.

INTRODUCTION

Stretcher-carrying is a physically-demanding task in which muscular fatigue may be readily induced by sustained contractions (Lind and McNicol, 1968). During combat, field medics must be able to transport, protect, and medically treat patients. The skills involved in weapon firing and patient treatment may be disrupted by the near maximum physical effort required by stretcher-carrying.

The purpose of this study was to determine whether soldier performance would be enhanced by the use of an ergonomically designed stretcher-carry harness. An additional purpose was to determine if the effects of harness use would be more pronounced depending on team size and gender of stretcher-bearers.

METHODS

A two-factor (2x2) repeated measures design focusing on harness and team size was used. The physical characteristics of the twelve male and eleven female volunteers are in Table 1. Maximal oxygen uptake was determined using a discontinuous, progressive protocol on a motorized treadmill (Mitchell, Sproule and Chapman, 1957). Body composition was assessed using hydrostatic weighing and residual volume was measured in

Table 1. Male and female physical characteristics (Mean ± Standard Deviation).

CHARACTERISTIC	MALES	FEMALES
Age (yrs)	20.8 ± 2.6	23.6 ± 4.0
Height (cm)	178.4 ± 7.5	162.6 ± 7.1
Weight (kg)	79.2 ± 13.1	58.1 ± 6.2
% Body Fat	15.4 ± 4.0	24.9 ± 6.5
Bench Press Max (kg)	85.8 ± 19.5	38.8 ± 6.4
Dead Lift Max (kg)	135.1 ± 23.2	82.1 ± 11.5
$\dot{V}O_2$ Max ($l \cdot min^{-1}$)	4.2 ± 0.4	2.4 ± 0.4
Grip Strength (kg)	51.3 ± 9.4	35.3 ± 9.6

duplicate using the oxygen dilution method (Wilmore, 1969). Written informed consent was obtained following a detailed briefing and medical screening.

General Procedure

Soldiers carried a military stretcher loaded with a 81.6 kg manikin (similar to the 78.5 ± 11.0 kg weight of the 50th percentile male U.S. Army soldier) on a treadmill (Figure 1). Immediately before and after stretcher-carrying, soldiers completed a marksmanship and fine-motor coordination task. Soldiers carried the stretcher with a harness (Figures 2 and 3) and with their hands, in two- and four-person teams.

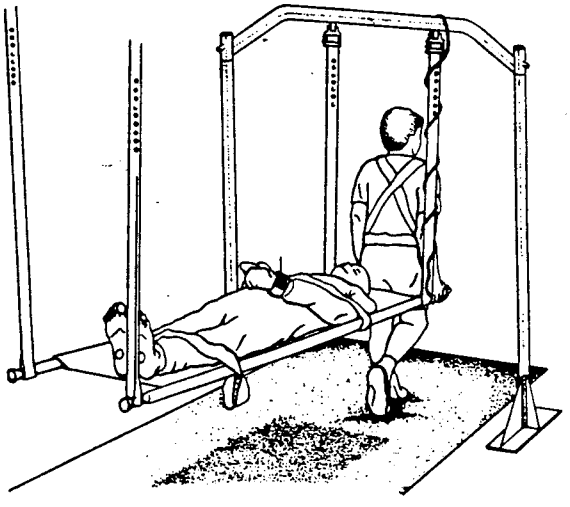

Figure 1. Stretcher-carry test station.

Carrying a single patient from a remote site to a waiting ambulance was simulated. The task required soldiers to carry a stretcher for as long as possible, up to a total of 30 min at a fixed, moderate speed of 4.8 km/hr. Soldiers had a minimum of 48 hours rest between carries.

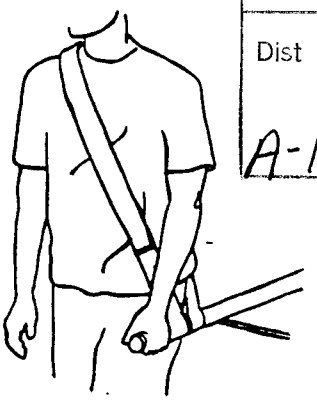

Figure 2. Four-person Harness.

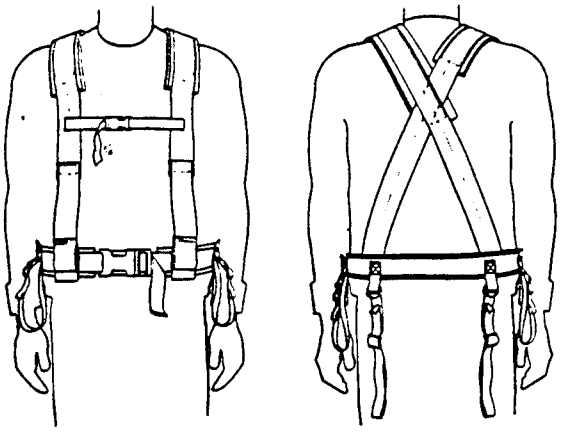

Figure 3. Two-person Harness.

Marksmanship. A disabled M-16 rifle equipped with a laser marksmanship simulator system was used. A computer program was used to convert scores to actual shot distances from target center (Marlowe, Tharion, Harman, and Rauch, 1989). The following measurements were used: distance from center of mass (DCM), shot group tightness (SGT), and sighting time. These marksmanship parameters have been defined previously (Tharion, Hoyt, Marlowe, and Cymerman, 1992).

Fine Motor Coordination. The cord and cylinder manipulation task is a bi-lateral fine-motor dexterity task which requires soldiers to thread a series of eleven loops of 0.24 cm nylon cord through 10 cylinders. The time required to complete the task is the subject's score (Johnson, 1981). Soldiers were trained to asymptotic level over a period of ten days (three consecutive test scores were within ± 2.5% of each other).

Heart Rate. Heart rate was recorded in one-minute increments throughout stretcher-carry testing using the UNIQ$_{tm}$ heartwatch system, which consists of an electrode strip and transmitter worn on the chest and a receiver worn on the wrist. The entire unit weighed 0.14 kg.

Oxygen uptake/percent of $\dot{V}O_2max$. Oxygen uptake was monitored throughout the stretcher-carry task. Soldiers breathed through a low resistance two-way Hans-Rudolf valve, and expired gases were directed into an on-line gas analysis system. Expired gas samples were collected continuously and averaged in 30 s intervals. Relative exercise intensity, expressed as percent of maximal O_2 uptake, was calculated by dividing each soldier's exercising O_2 uptake by their maximal O_2 uptake ($\%\dot{V}O_2max$) expressed in units of ($ml \cdot kg^{-1} \cdot min^{-1}$).

Rating of Perceived Exertion. Soldiers rated their exertion level immediately following each carry on a fifteen-point Likert-type scale (Borg, 1978).

Analysis of variance (ANOVA) procedures were performed on dependent measures. Newman-Keuls Multiple Comparison Tests were used to determine the differences between means of significant interactions.

RESULTS

Men carried the stretcher longer than women (18.61 ± 11.25 min vs 10.65 ± 10.19 min; $p < 0.0001$). Four-person teams carried the stretcher longer than two-person teams (16.91 ± 11.04 min vs 12.35 ± 11.44 min; $p < 0.0001$). Harness carries were longer than hand carries (23.12 min vs 6.14 min; $p < 0.0001$). Male four-person teams carried the stretchers longer than any other team size x gender combination ($p < 0.01$), and male two-person teams carried the stretcher longer than female two-person teams ($p < 0.01$, Table 2).

Table 2. Continuous carry times (min) for men and women.

Carry Type	Males mean, ± SD (range)	Females mean, ± SD (range)
2-person hand	4.2 ± 1.8 (2.1 - 8.4)	1.8 ± 1.0 (1.1 - 4.5)
2-person harness	26.4 ± 5.6 (16.9 - 30.0)	17.1 ± 9.3 (6.6 - 30.0)
4-person hand	13.9 ± 6.9 (6.7 - 30.0)	4.7 ± 1.2 (3.3 - 6.76)
4-person harness	30.0 ± 0 (30.0)	24.0 ± 10.5 (9.3 - 30.0)

Post-carry rifle marksmanship was less accurate as depicted by DCM (pre-carry: 7.7 ± 1.6 mm, post-carry: 8.1 ± 1.7 mm; $p=0.02$) across all conditions. The most dispersed SGT (accuracy) for all harness x gender combinations was attained by men after hand carries ($p < 0.01$, Figure 4). Two-person male teams had poorer speed and accuracy SGT post-carry than all other post-carry team size x gender combinations ($p < 0.05$, Figure 5).

Women completed the fine-motor task faster than men (women: 41.3 ± 4.9 sec, men: 53.3 ± 7.4 sec; $p < 0.0001$). Task performance was slower post-carry, compared with pre-carry (pre: 46.1 ± 8.2 sec, post: 48.5 ± 9.1 sec; $p = 0.002$). Soldiers completed the task more slowly after the hand-carry than either of the

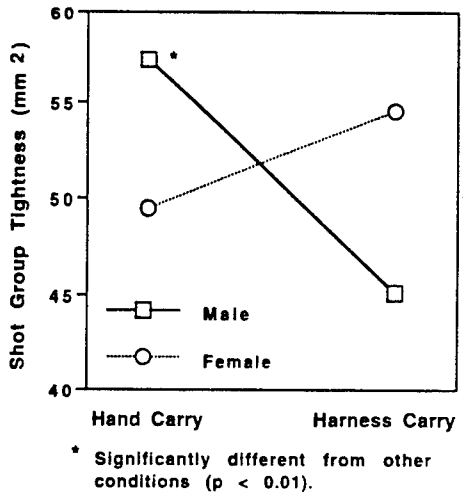

Figure 4. Shot Group Tightness (accuracy).

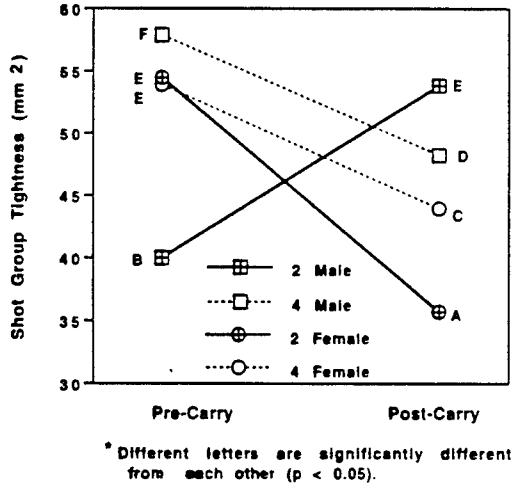

Figure 5. Shot Group Tightness (speed and accuracy).

pre-carry conditions ($p < 0.05$, Figure 6).

Heart rate was higher for women than for men across all conditions (women: 158.2 ± 10.9 beats/min, men: 133.6 ± 11.9 beats/min; $p < 0.0001$). Heart rate was lower during harness versus hand carries (harness: 141.9 ± 14.7 beats/min, hand: 149.8 ± 17.9 beats/min; $p = 0.0004$).

Men worked at a lower $\%\dot{V}O_2$ max than women (41.1 ± 6.4 % vs 46.8 ± 8.8%; $p = 0.01$). Two-person teams worked at a higher $\%\dot{V}O_2$ max than four-person teams (45.3 ± 8.4% vs 42.5 ± 7.6%, $p = 0.04$). Soldiers worked at a higher $\%\dot{V}O_2$ max when using a harness than without (45.8 ± 8.5% vs 42.1 ± 7.4%; p 0.02). Each of the gender by harness groups worked at a significantly different $\%\dot{V}O_2$ max from each other ($p < 0.05$, Figure 7).

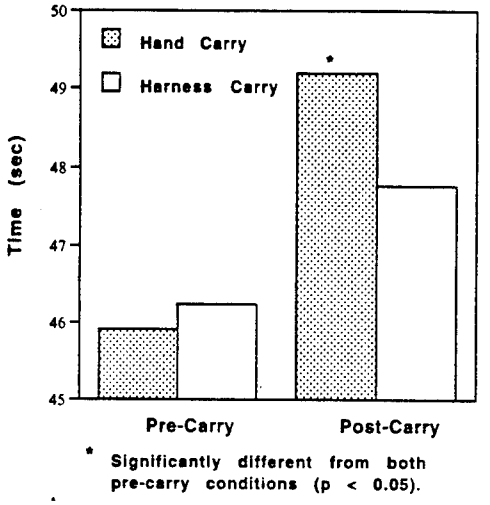

Figure 6. Cord and Cylinder Task.

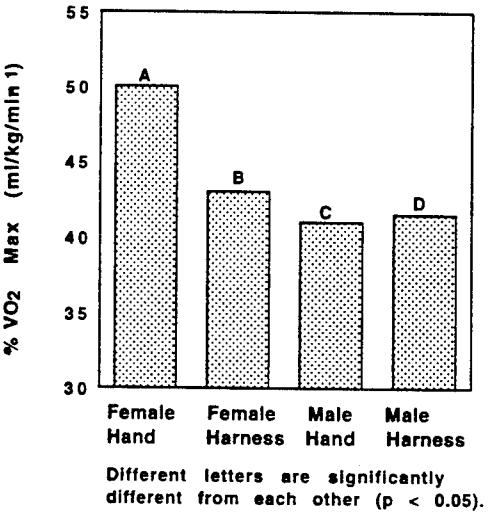

Figure 7. $\%\dot{V}O_2$ max.

Less subjective exertion was reported after carrying the stretcher in the hands than with a harness (5.3 ± 2.2 vs 6.2 ± 1.9; $p = 0.03$).

DISCUSSION

Men carried the stretcher longer than women. Both four-person teams and harness use increased carry time for men and women.

Carrying a stretcher prior to firing an M-16 rifle resulted in a decrease in shooting accuracy; however, using a harness did not affect shooting performance. It is somewhat surprising that shooting accuracy was not poorer following

harness carries, since harness carry time was considerably longer than hand carry time and soldiers used more of their total aerobic capacity while carrying with a harness.

Women had a tighter shot group (accuracy) during hand carries, probably indicating that the length of the hand carry was not long enough to disrupt overall performance (women's mean = 1.79 min). Men had a tighter shot group (accuracy) after carrying with a harness. Although men's endurance time was much longer with a harness, they were stopped before reaching their fatigue level. The combined lack of overall fatigue with little or no localized handgrip fatigue during harness use may explain soldiers proficiency in maintaining marksmanship accuracy.

Male two-person teams had the poorest post-carry speed and accuracy SGT, probably because of the fatigue effects being greater, i.e. each individual carried half the weight they carried in four-person teams. Also, four-person teams were limited by the weakest team member, therefore half of the soldiers would not have carried the stretcher at their maximal limit. Carrying in two-person teams, even with a harness, probably resulted in enough overall physical fatigue to mask any gains achieved by reducing fatigue to the hands and arms.

Carrying a stretcher increased the time it took to complete a fine-motor task. Although the total carry time was considerably shorter for hand vs harness carries, completion of the fine-motor task took longer, and heart rate was higher following the hand carry. The sustained grip required during the hand carries probably resulted in a pressor response similar to that found by Lind and McNicol (1968). Combined with local muscle fatigue, these two factors interfered with fine-motor coordination.

CONCLUSIONS

The ability to transport, medically treat, and maintain marksmanship accuracy was improved by using an ergonomically- designed harness. The use of a four-person team helped increase the time of carries when compared to the same harness condition two-person team, and decreased the overall physiological demand of the task (as indicated by oxygen consumption). Four-person teams' fine-motor and marksmanship scores were maintained at pre-carry levels. Two-person teams using a harness carried substantially longer than four-person teams without a harness. It is suggested that the policy of using four-person teams be enforced, and that harness systems be included with the supply of stretchers for any situation that requires continuous stretcher-carrying of five minutes for four-person teams and two minutes for two-person teams.

ACKNOWLEDGEMENTS

We acknowledge Tania Williamson, M.S. and Lt. Brian Boutilier for their contributions during data collection and analysis.

REFERENCES

Borg, G. (1978). Subjective aspects of physical and mental load. Ergonomics, 21 (3), 215-220.

Johnson, R.F. (1981). Effects of explosive ordnance disposal armor on the gross body mobility, psychomotor performance, speech intelligibility, and visual field of men and women (Tech. Report 81-031). Natick, MA: U.S. Army Research Institute of Environmental Medicine.

Lind, A.R., and McNicol, G.W. (1968). Cardiovascular responses to holding and carrying weights by hand and by shoulder harness. Journal of Applied Physiology, 25, (3), 261-267.

Marlowe, B., Tharion, W., Harman, E., and Rauch, T. (1989). New computerized method for evaluating marksmanship from Weaponeer printouts (Tech. Report T3-90). Natick, MA: U.S. Army Research Institute of Environmental Medicine.

Mitchell, J.H., Sproule, B.J., and Chapman, C.B. (1958). The physiological meaning of the maximal oxygen intake test. Journal of Clinical Investigation 37, 538-547.

Tharion, W.J., Hoyt, R.W., Marlowe, B.E., and Cymerman, A. (1992). Effects of high altitude and exercise on marksmanship. Aviation, Space, and Environmental Medicine, 63, 114-117.

Wilmore, J.H. (1969). A simplified method for determination of residual lung volumes. Journal of Applied Physiology, 27, 96-100.